CHAPTER 8

ACCESSORY SYSTEMS

Accessories for gas turbine engines can be divided into two categories those driven by bleed air taken from the compressor section of the engine; those driven mechanically by an accessory drive shaft and gearbox connected directly to the turbine shaft. The mechanical connection from the turbine shaft may be through an engine-mounted gearbox or through a power takeoff shaft to a remotely mounted gearbox.

BLEED-AIR-DRIVEN ACCESSORIES

Gas turbines are unique among engines. High--pressure air is available for driving aircraft accessories by air motors or air turbines. Compressor discharge air at high pressure and temperature is bled from the engine through ports provided. This air is ducted as a source of power. It operates the air-conditioning units, hydraulic pumps, thrust reverser actuators, and various mechanical actuators in the airplane. Air for cockpit or cabin pressurization is also provided by bleed air from the engine compressor. On multiengined aircraft equipped with pneumatic engine starters, one engine is usually started from an auxiliary power unit or a ground air source. Air from this operating engine is bled through a system of ducts in the aircraft, to power the starters of the other engines.

The Pratt and Whitney dual-axial compressor turbine engine is an example that uses bleed air to operate accessories. The JT3D turbofan engine is used on aircraft such as the Boeing 707 and B-52 bomber. This engine also uses a mechanical accessory gearbox. It usually has three separate bleed air systems: high pressure, low pressure, and overboard. The high- and low-pressure systems are used to drive aircraft, engine components, and accessories. The overboard is required to preclude compressor instability.

Compressor bleed air is also used to anti-ice the engine air inlet guide vanes and, frequently, parts of the air inlet duct. Low-pressure air has a pressure of approximately 50 psi and a temperature of more than 300°F. This low-pressure air is taken from bleed air parts compressor mid-section between the low- and high-pressure compressors. High-pressure bleed air has a pressure of about 160 psi and a temperature of more than 650°F when operating near sea level. This air is taken from the rear of the high-pressure compressor. The air available for driving accessories and for other purposes in the aircraft is usually about 3 or 4 percent of the primary engine airflow. Keep in mind the air under pressure that is extracted from the engine is not a bonus. Engine output and fuel consumption are sacrificed.

MECHANICALLY DRIVEN ACCESSORIES

The other method of driving accessories is a direct, mechanical drive operated by gearing from the compressor-turbine drive shaft. Accessory drives and accessory mounting pads are provided in an engine-mounted, accessory drive gearbox or in a remotely mounted gearbox. On some turbojet engines, accessory pads and mechanically powered drives are also provided in the engine nose section. For dual compressor, axial-flow engines, the main accessory drive gearbox usually receives its power from the high-pressure compressor drive shaft. Mechanically driven accessories include: tachometers, generators (alternators), hydraulic pumps, fuel pumps, oil pumps, fuel controls, starters, and (ii some instances) water pumps.

LYCOMING T-55 ENGINE

The power extraction system transmits power from the N1 and N2 systems to the accessory gearbox located at the 6 o'clock position on the inlet housing (Figures 8-1, 8-2). Most of these components receive their driving force from the N1 system. A minimum amount of power is extracted from the N2 system.

The starter gearbox, mounted at the 12 o'clock position, functions as a centrifuge for air-oil separation during engine operation. The N1 system provides the driving force. A single bevel gear is located at the front end of the compressor shaft; meshes with a planetary geartrain housed in the inlet housing This gear train transmits N1 power through two drive shafts: one to the starter gearbox, the other to the accessory gearbox to drive the idler system. A gear located on the output power shaft

Gearshaft assembly (1) and gearshaft (2) are located in the starter drive assembly. Bevel gearshafts (18 and 20) and bevel gear (19) are located in the accessory gear assembly. The fuel boost pump drive gear (6), main oil pump drive spur gear (7), fuel control drive spur gear (8), N1 driven bevel gear (9), overspeed governor control drive bevel spur gearshaft (10), spur gear cluster (11), spur gear (12), and N2 driven bevel gear (13) are located in the accessory gearbox assembly. The N2 driven bevel gearshaft (14) is part of the overspeed drive and tank outlet cover assembly. Overspeed drive bevel gear (15) and spur gear (16) are part of the output shaft support housing (not shown). The output shaft (17) is mounted and rotates through the output shaft support housing. Bevel gear (3) is part of the compressor rotor assembly (4).

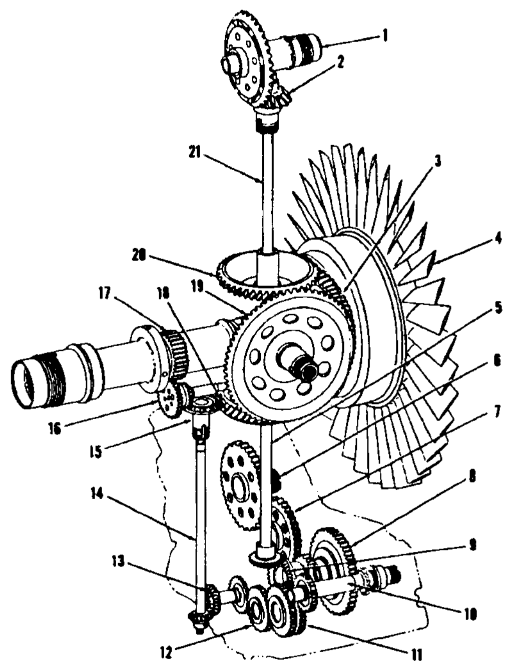

Figure 8-1. Power Extraction System and Gearbox

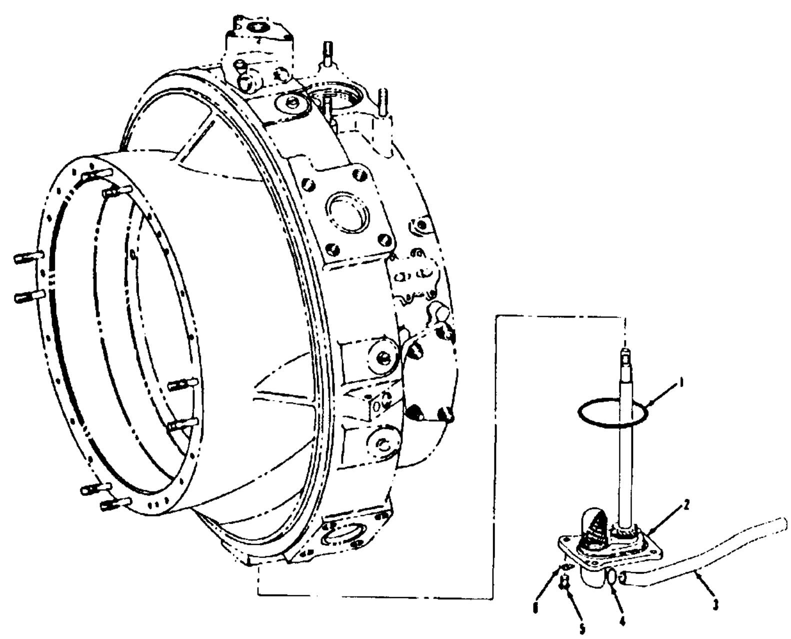

Figure 8-2. Overspeed Drive Cover Assembly

interconnects with the 90° angle gear in the output shaft support housing. The gears drive the N2 section of the accessory gear train.

The N2 driven overspeed governor in the fuel control is driven from a spur gear. This gear is attached to the N2 system drive shaft which rotates on a ball bearing with a pad, located at the 6 o'clock position on the inlet housing

Customer power extraction is provided through the vertical bevel pinion gear located within the accessory gear carrier. It is available for use by inserting a customer-supplied drive shaft in its internal splines.

The accessory drive gearbox supplies mounting pads for the engine-supporting accessories and provides the transmission capability to drive these components. Dimensional standardization permits interchanging components among engines and eliminates the need for adapters for test equipment.

GENERAL ELECTRIC T-701

The accessory module mounts on the cold section module at the 12 o'clock position of the main frame (Figures 8-3, 8-4). It includes the accessory drive gearbox (AGB) that is driven by a bevel-gear system from the compressor rotor via a radial drive shaft. Several accessories are contained in or mounted on the front and rear casings of the AGB. The rear face provides drive pads for the engine starter, hydromechanical unit, inlet separator blower, and a face-ported pad for the overspeed and drain valve. Pads for the alternator and fuel boost pump are on the front face. A cavity is provided for the lube and scavenge pump and chip detector. Pads are supplied for the oil cooler, fuel meter, and lube falter. Cored passages in the AGB housing convey fuel and oil between components.

Drive pad seals for the starter, hydromechanical unit, and fuel boost pump drain into a common cored passage in the AGB housing. It then drains to an external port on the right-hand side of the mainframe.

ACCESSORY DRIVES

Accessory Drive System

The accessory drive system provides drives for both the N1 driven accessory gearbox and the N2 driven overspeed governor and tachometer drive assembly. Provision is also made within the system for the drive of customer-furnished accessories through the power

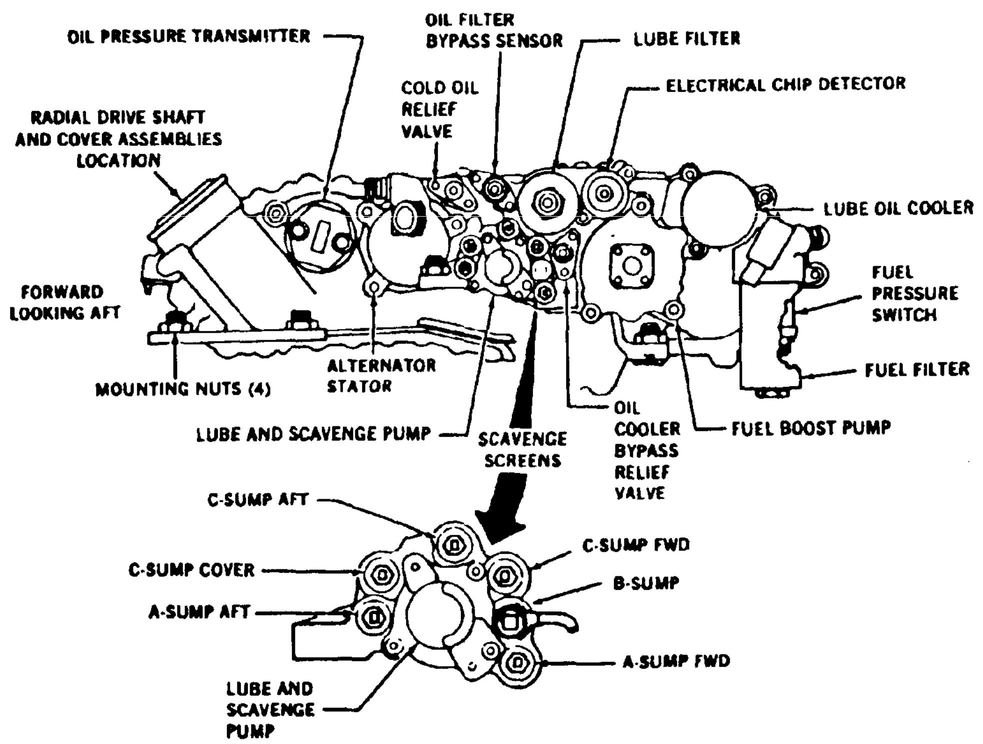

Figure 8-3. (T-701) Component Locations on Accessory Section Module

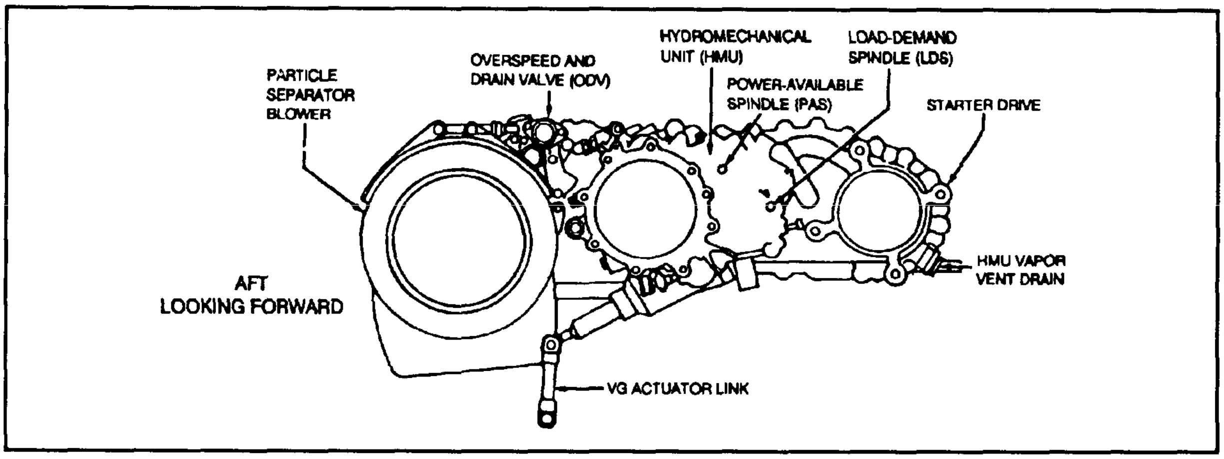

Figure 8-4. (T-701) Component Locations on Accessory Section Module

takeoff pad located at the 2 o'clock position on the engine inlet housing (Figure 8-5).

N_1 drive is provided from a pinion gear (9) mounted on the forward end of the compressor rotor shaft, driving two bevel gears (10 and 19) located within the accessory gear carrier.

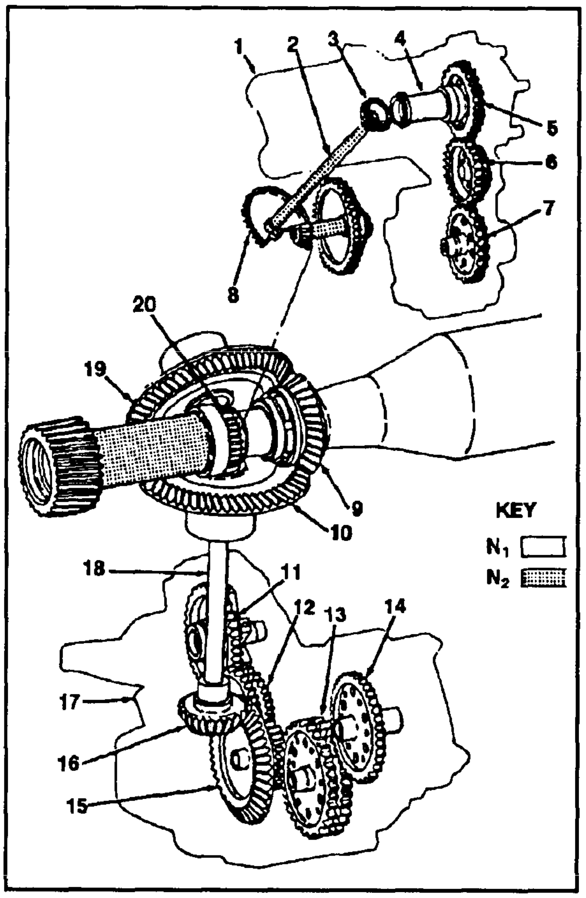

Figure 8-5. Accessory Drives (K-4 Gearing)

The bevel gear located at the 6 o'clock position within the carrier, being the accessory gearbox drive gear (10), is splined internally to accept the accessory gearbox shaft (18). This drive shaft connects the gear carrier to the accessory gearbox through the 90° pinion gear (16) which in turn is splined directly to the starter-generator drive gear (15). The starter-generator drive gear provides drive to all subordinate gears located with the accessory gearbox housing.

The power takeoff drive is provided through the second bevel gear (19) located within the accessory gear carrier and is used to drive airframe accessories.

The N_2-driven overspeed governor and tachometer drive gearbox (1) receives its drive from a spur gear (20) pressed to the power shaft aft of the sun gear. This gear engages the N_2 drive and driven gear package (8) located within the accessory gear carrier. This package, a series of three gears, provides an internal spline drive for the drive shaft (2) which passes up through the 10 o'clock inlet housing strut and into the gearbox (l).

The drive shaft then engages the internal splines of the upper drive gear (3) which provides drive to the tachometer gear (5). This gear meshes directly with an idler gear (6) which in turn transmits the drive to the combination torquemeter boost pump and overspeed governor drive gear (7).

Main Accessory Drive Gearbox

The accessory drive gearbox (Figure 8-6) is mounted at the 6 o'clock position of the engine inlet housing and is driven through bevel gears from the front end of the compressor rotor. Drive pads are provided on the rear of the gearbox for the fuel control, the starter-generator, and the gas producer (nI) tachometer generator. The gearbox front side has mounting for the rotary oil pump and also has an unused drive pad with connection line. Oil scavenge lines are connected at the right rear on the gearbox which serves as an oil collector sump, kept practically empty by the pump. A chip detector plug is located in the lower right side, and the oil filter is on the left side. A drain line from the inlet guide vane actuator is connected to the right side.

Accessories driven by the power turbine gear train are the power turbine tachometer-generator (N_2 and the power turbine governor. The gas producer gear train drives the oil pump, fuel pump, gas producer fuel control, and tachometer-generator (N_1). The gearbox has a spare accessory mounting pad which is driven by the gas producer gear train. During starting the starter-generator cranks the engine through the gas producer gear train. After

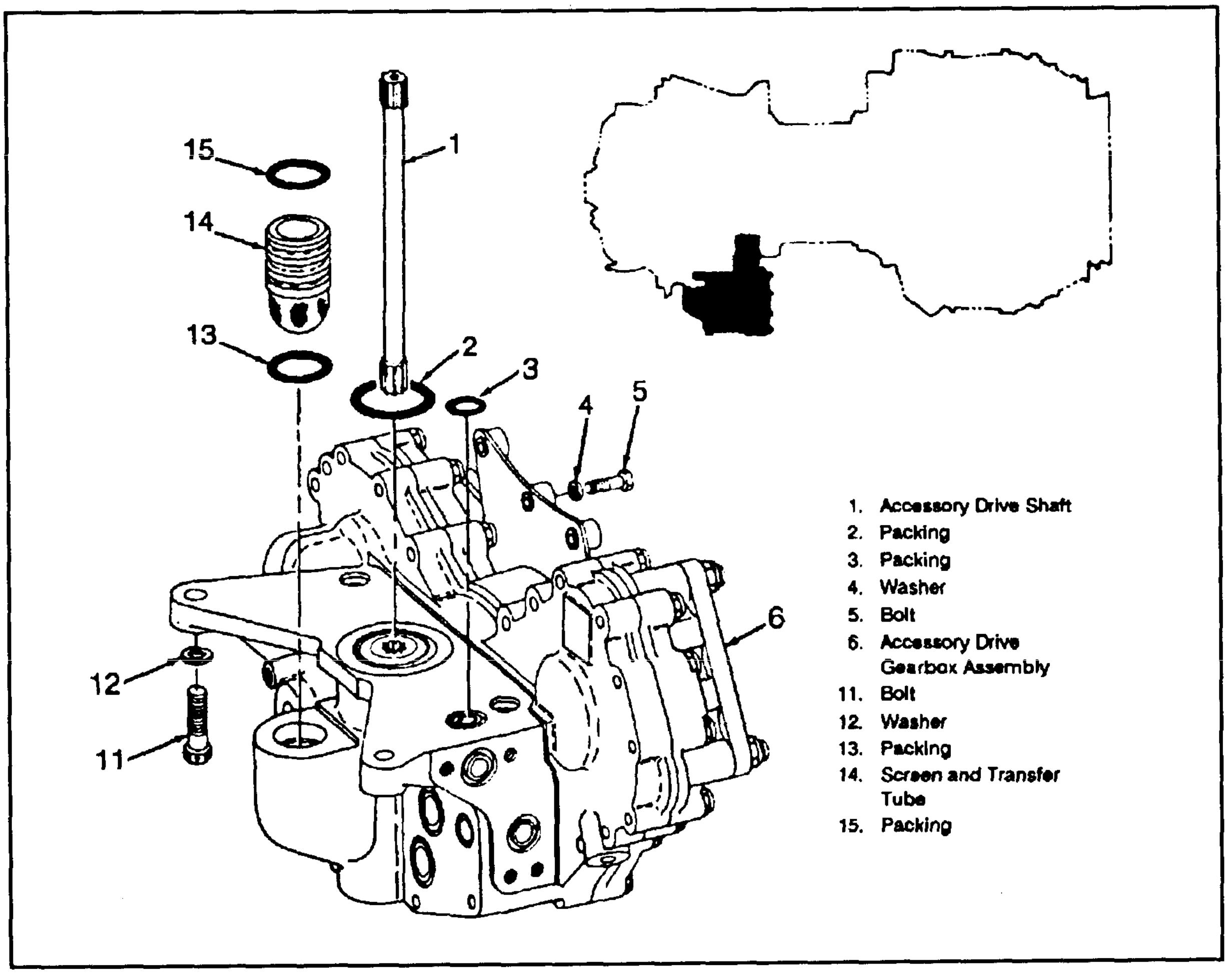

Figure 8-6. Main Accessory Drive Gearbox

Power and Accessory Gearbox

The main power and accsessory drive gear trains are enclosed in a single gear case. The gear case serves as the structural support of the engine. All engine components, including the engine-mounted accessories, are attached to the case. At 100 percent engine speed, reduction gearing reduces power turbine speed from 33,290 to 6016 RPM at the output drive pads. The power turbine gear train has a torquemeter to measure engine output torque.

completion of the starting cycle, the starter-generator functions as a generator.

STARTERS

Gas turbine engines are started by rotating the compressor. In the case of dual axial-flow compressor engines, the high-pressure compressor is usually the only one rotated by the starter. First, compressor accelerates to provide sufficient air under pressure to support combustion in the burners. Second, after fuel is introduced and the engine is fired, starter continues to assist the engine above the self-sustaining speed. The torque must be in excess of that required to overcome rotor inertia and engine friction and air loads.

Basic types of starters developed for gas turbine engines are air turbine (pneumatic), electric motor, hydraulic, combustion, and cartridge pnuematic. Air turbine starters are the most commonly used. Smaller engines generally use electric starters. Hydraulic starters are frequently found in helicopters and some marine gas turbine installations. Combustion and cartridge-pneumatic starters are generally special application devices that may require a self-contained starting system. An impingement starting system is sometimes used An impingement starter consists of simple jets of compressed air piped to the inside of the compressor or turbine case. The jet air blast is directed onto the compressor or turbine rotor blades and causes them to rotate.

As the starter accelerates the compressor sufficiently to establish airflow through the engine, the ignition and then the fuel are turned on. The exact sequence of the starting procedure is important. There must be sufficient airflow through the engine to support combustion when the fuel-air mixture is ignited The fuel flow rate will not be sufficient to enable the engine to accelerate until after the self-sustaining or self-accelerating speed has been reached If assistance from the starter were cutoff below the self-sustaining speed, the engine would either fail to accelerate to idle speed or decelerate. Deceleration occurs because sufficient energy was not produced to sustain rotation or acceleration during the initial phase of the starting cycle. The starter must continue to assist the engine above the self-staining speed to avoid a delay in the starting cycle. This would result in a hot or hung (false) start, or a combination of both. In a hot start, the engine lights up, but the exhaust gas temperature exceeds that allowed for an engine start. In hung or false start the engine lights up normally but, instead of increasing to idle speed, the RPM remains at some lower value.

At the proper points in the sequence, the starter and the ignition cut off. The higher the RPM before the starter cuts out, the shorter the total time required for the engine to attain idle RPM. The engine and starter work together to furnish the torque necessary for engine acceleration.

The most important requirement of a starter is to produce sufficient torque to start the engine properly. Engines must be rotated and accelerated above a certain minimum rate if consistently good starts are to be achieved. The torque characteristics of an acceptable starter must be well above the required minimum.

Air Turbine

Air-turbine starters (which are also called pneumatic starters) are used more than any other for starting jet aircraft engines, particularly larger engines (Figure 8-7). A small geared air turbine is attached to the engine starter pad located at the accessory drive gearbox. Air-turbine starters must receive compressed air from an external power source. A compressor mounted on a ground unit or onboard the aircraft is one such source. A small turbine engine usually drives these units. On multiengine aircraft, air is often bled from the first engine started and used to operate the starters for the remaining engines. With an air-turbine starter, the air supply must be of sufficient volume and pressure to meet starter requirements. Otherwise, the starter torque may not produce consistently successful starts within an acceptable time limit. When bled air from another operating engine is used, the engine being used for a compressed air supply must be turning over fast enough to ensure adequate air pressure to the starter of the engine being started

Still another form of pneumatic starter is when the starter itself is part of the ground power unit. The end of a flexible shaft from the starter is placed in a connection box on the engine to turn the compressor. When the engine starts, the flexible shaft is removed This type starter might be used on small gas turbine engines. It might also be used on a gas turbine engine for a missile or where airborne weight must be held to the minimum.

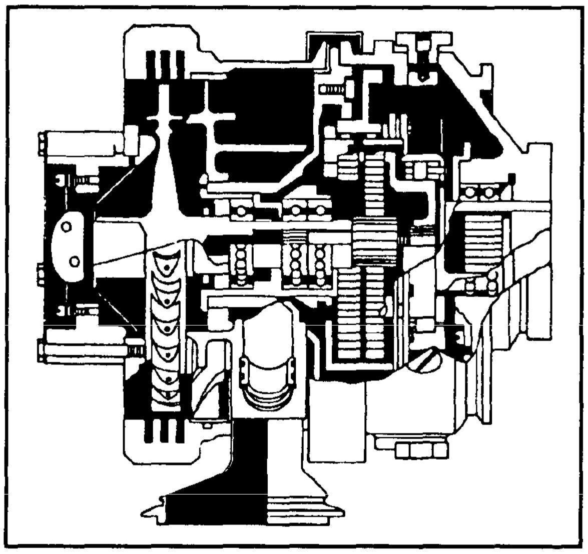

Figure 8-7. Air Turbine Starter

Combustion

A combustion starter is essentially a small turboshaft gas turbine engine (Figure 8-8). Its chief advantages are quick starts because of the high torque produced and portability. The complete starting system may be carried aboard the aircraft. This starter obtains its power from hot expanding gases. These gases are generated in the starter combustion chamber. They occur by burning a combustible mixture either fuel, air, or monopropellant. A monopropellant is a specially compounded solid or liquid slow-burning substance.

The quantity of fuel or monopropellant required by the starter is proportional to the length of time the starter is operating. Aircraft weight and size limitations require that the quantity of fuel or monoporpellant be held to a minimum in an airborne, combustion-starter system. The starter burning time must be held to a minimum. This is determined by the starter torque and the starter cutout speed. The starter cutout speed depends on the self-sustaining speed of the engine. The self-sustaining speed determines, to a large extent, the amount of fuel or monopropellant required. Ordinarily, sufficient fuel or monopropellant to provide a minimum of two starts will be carried aboard the aircraft. Some combustion starters operate as simple air turbines. When an outside air source from a ground unit or another engine which is already started is connected to the starter, the combustion starter functions as a pneumatic starter.

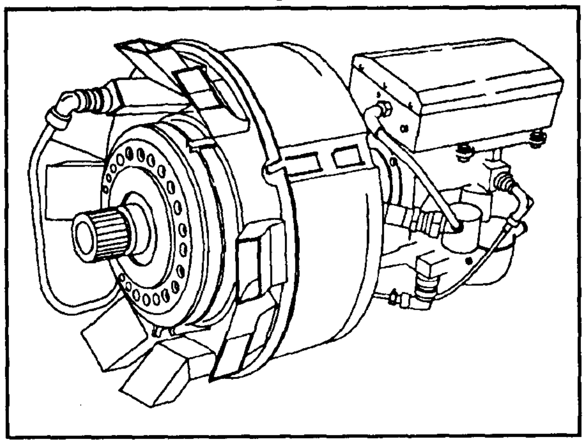

Figure 8-8. Fuel-Air Combustion Starter

Cartridge Pneumatic

A cartridge-pneumatic starter is a combustion starter that operates from monopropellant contained in a cartridge. Prior to starting, the monopropellant cartridge is inserted in the starter. Like a regular combustion starter, a cartridge starter fires electrically from a switch in the aircraft. Cartridge-pneumatic starters can be operated as pneumatic starters when provided with outside air.

Electric Starting

Direct cranking and starter generator are the two electric starting systems for gas turbine aircraft (Figure 8-9).

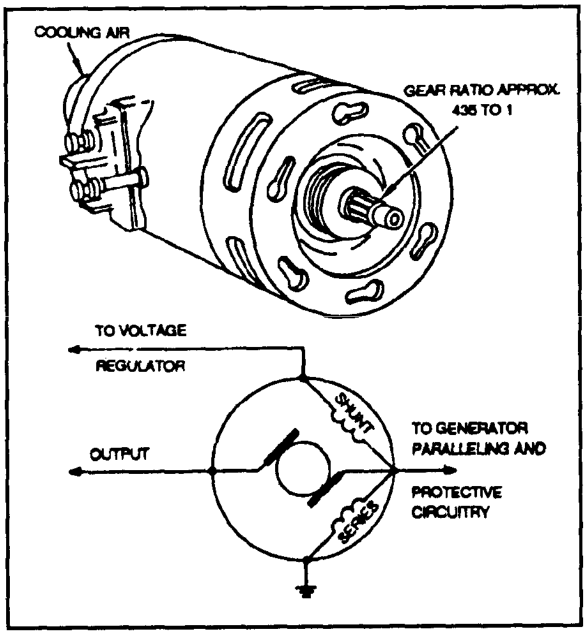

Figure 8-9. Typical Starter-Generator

Direct-cranking electric starting systems are similar to those used on reciprocating engines. Starter-generator starting systems are also similar to direct-cranking electrical systems. Electrically, the two systems may be identical. But the starter generator is permanently engaged with the engine shaft through the necessary drive gears. The direct-cranking starter must use some means of disengaging the starter from the shaft after the engine has started.

Direct-Cranking Gas Turbine Starters. On some gas turbine engines, no overload release clutch or gear reduction mechanism is used. This is because of the low-torque and high-speed requirement for starting. A reduced voltage mechanism is used, however, in the starting assembly during starting.

Starter-Generator Starting System. Many gas turbinc aircraft are equipped with starter-generator systems. These starting systems use a combination starter-generator which operates as a starter motor to drive the engine during starting. After the engine reaches a self-sustaining speed, the starting system operates as a generator to supply the electrical system power.

The starter-generator unit is basically a shunt generator with an additional heavy series winding. This series winding is electrically connected to produce a strong field and a resulting high torque for starting. Start-generator units are desirable from an economical standpoint. One unit can perform the function of both starter and generator. Additionally, the total weight of starting system components is reduced, and fewer spare parts required